Dynamic Price Setting

- Romer begins Chapter 7 on dynamic new Keynesian models with a general framework for dynamic price setting
- In our analysis of menu costs and real/nominal rigidity of prices, we have considered only a static framework: a one-time decision with given initial prices
- Actual price decisions occur in a dynamic setting in which the prices set today are likely to persist into next period.
- The key question of this section is: **"What is the dynamic-optimal price to set if the price is likely to be in effect for multiple periods?"**
  - The intuitive answer is **"an average of the expected static-optimal price for each future period, weighted by the probability that the price is in effect for that period."**

Modeling dynamic price setting

- Model of Romer's Section 7.1
  - Mostly similar to our previous models
  - Most of the complexity in this model is either not interesting or is ultimately assumed away by Romer in his approximation toward the end of the section
  - We will focus on the basics of the model that comes out rather than the details of the derivation
    - (Some material on the derivation are in the Coursebook if you want them.)
- **Static-optimal price**
  - Based on conditions at time t (if we know them) there is a price that is optimal for the firm in that period.
    - This is just the same p^* that we have had in the models of Chapter 6
  - From Romer's (7.16), $p^* = p + \ln\left(\frac{\eta}{\eta-1}\right) + b + (\theta+\gamma-1)y$
    - The only thing new here is the b, which is introduced for convenience to get rid of the $\ln(\eta/(\eta\text{-}1))$ term, since we will assume that they cancel
  - Let $\phi = \theta+\gamma-1$ and $b + \ln\left(\frac{\eta}{\eta-1}\right) = 0$ by assumption, so

    $p_t{}^* = p_t + \phi(m_t - p_t) = \phi m_t + (1-\phi)p_t$
  - This is our static-optimal price for period t
- **Dynamic-optimal price**

- Following our intuition, suppose that q_t is the probability that a price set at time 0 is still in effect at time t
  - Fixed-price contracts would have $q_t = 1$ for duration of contract, and 0 afterward
- Dynamic-optimal price is weighted average of static-optimal prices with weights given by probabilities q_t: $p = \sum_{t=0}^{\infty} q_t E_0\left(p_t^*\right) \times \frac{1}{\sum_{\tau=0}^{\infty} q_t}$, where we the denominator is the sum of the weights, which we need to make sure that the weights add up to one
- Let $\omega_t = \frac{q_t}{\sum_{\tau=0}^{\infty} q_\tau}$, where the denominator can be interpreted as the expected number of periods that a price will be in effect.
- Dynamic-optimal $p = \sum_{t=0}^{\infty} \omega_t p_t^* = \sum_{t=0}^{\infty} \omega_t E_0\left(\phi m_t + (1-\phi) p_t\right)$
  - For fixed-price contract of length n, $\omega_t = \frac{1}{n}$ for the n periods of the contract and zero afterward
  - For Calvo model with probability of price re-set of α per period, $q_t = (1-\alpha)^t$ and $\omega_t = \frac{(1-\alpha)^t}{\sum_{\tau=0}^{\infty}(1-\alpha)^\tau} = \frac{(1-\alpha)^t}{1/\left(1-(1-\alpha)\right)} = \alpha(1-\alpha)^t$

- To determine the optimal price and the resulting dynamics of the economy, we need to describe the pattern of price re-setting over time
  - Fischer model of "predetermined prices": Two-period overlapping contracts with different price for first and second periods
  - Taylor model of "fixed-price" contracts: Two-period overlapping contracts with same price for both periods
  - Calvo model: Fixed probability α that price will be re-set in any period

Predetermined Prices: Fischer Model

- Adaptation of Fischer's original model based on wage contracts, where firm and workers can set different wages for the different periods of the contract
- Two equal-sized sets of firms:
  - Group A sets prices at beginning of odd-numbered periods
  - Group B sets prices at beginning of even-numbered periods
- Notation:

- p_t^1 is price set for period t for first period of contract
    - Set at beginning of t
- p_t^2 is price set for period t for second period of contract
    - Set at beginning of $t-1$
- Note that $p_{t+1}^2 \neq p_t^1$ in general

t	1	2	3	4	5	6
Group A	p_1^1	p_2^2	p_3^1	p_4^2	p_5^1	p_6^2
Group B	p_1^2	p_2^1	p_3^2	p_4^1	p_5^2	p_6^1
p_t	$\frac{p_1^1+p_1^2}{2}$	$\frac{p_2^1+p_2^2}{2}$	$\frac{p_3^1+p_3^2}{2}$	$\frac{p_4^1+p_4^2}{2}$	$\frac{p_5^1+p_5^2}{2}$	$\frac{p_6^1+p_6^2}{2}$

- Double lines are times at which prices are set (new contracts)
- $p_t = \frac{1}{2}\left(p_t^1 + p_t^2\right)$ is aggregation of price level in period t
- At end of $t-1$, group sets $p_t^1 = E_{t-1}\left(p_t^*\right)$ and $p_{t+1}^2 = E_{t-1}\left(p_{t+1}^*\right)$
- From optimal price-setting model above, $p_t^* = \phi m_t + (1-\phi)p_t$
- Putting these together,
    - $$\begin{aligned} p_t^1 &= \phi E_{t-1} m_t + (1-\phi) E_{t-1} p_t \\ &= \phi E_{t-1} m_t + \tfrac{1}{2}(1-\phi)\left(p_t^1 + p_t^2\right) \end{aligned}$$
    - $$\begin{aligned} p_t^2 &= \phi E_{t-2} m_t + (1-\phi) E_{t-2} p_t \\ &= \phi E_{t-2} m_t + \tfrac{1}{2}(1-\phi)\left(p_t^2 + E_{t-2} p_t^1\right) \end{aligned}$$
    - Taking the expectation as of $t-2$ of the top equation (which is needed in the bottom one),
      $$\begin{aligned} E_{t-2} p_t^1 &= E_{t-2}\left[\phi E_{t-1} m_t + \tfrac{1}{2}(1-\phi)\left(p_t^1 + p_t^2\right)\right] \\ &= \phi E_{t-2} m_t + \tfrac{1}{2}(1-\phi)\left(E_{t-2} p_t^1 + p_t^2\right) = p_t^2 \end{aligned}$$
      (with last equality coming from expression above)
    - So
      $$\begin{aligned} p_t^2 &= \phi E_{t-2} m_t + (1-\phi) p_t^2 \\ \left[1-(1-\phi)\right] p_t^2 &= \phi p_t^2 = \phi E_{t-2} m_t \\ p_t^2 &= E_{t-2} m_t \end{aligned}$$

- And

$$p_t^1 = \phi E_{t-1}m_t + \tfrac{1}{2}(1-\phi)\left(p_t^1 + E_{t-2}m_t\right)$$

$$\left[1-\tfrac{1}{2}(1-\phi)\right]p_t^1 = \tfrac{1}{2}(1+\phi)\,p_t^1 = \phi E_{t-1}m_t + \tfrac{1}{2}(1-\phi)\,E_{t-2}m_t$$

$$p_t^1 = \frac{2\phi}{1+\phi}E_{t-1}m_t + \frac{1-\phi}{1+\phi}E_{t-2}m_t$$

$$= E_{t-2}m_t + \frac{2\phi}{1+\phi}\left[E_{t-1}m_t - E_{t-2}m_t\right]$$

- So

$$p_t = \tfrac{1}{2}\left(p_t^1 + p_t^2\right) = E_{t-2}m_t + \frac{\phi}{1+\phi}\left[E_{t-1}m_t - E_{t-2}m_t\right].$$

- SRAS curve is horizontal at this "predetermined" price level and output is determined by AD

• From the AD curve:

$$y_t = m_t - p_t = \left[m_t - E_{t-1}m_t\right] + \frac{1}{1+\phi}\left[E_{t-1}m_t - E_{t-2}m_t\right]$$

• This equation expresses y_t as a function of two "AD surprises"
    - $\left[m_t - E_{t-1}m_t\right]$ is the current period surprise to AD$_t$
    - $\left[E_{t-1}m_t - E_{t-2}m_t\right]$ is last period's surprise to AD$_t$
    - The former is like the Lucas model's term (without the *b* coefficient), showing that current AD shocks will cause output fluctuations
    - The latter is a lagged output shock indicating that AD shocks affect output for *two* periods: the length of the longest contract that was fixed before the shock was known
• Intuition
    - Suppose a shock occurs to AD that is learned in period 1
    - p_1^1, p_1^2, and p_2^2 are all set before the contract is signed
    - Although p_2^1 is set after the shock is revealed, price setters will have to compete against p_2^2 which is already set too low/high because the information was not known
    - To the extent that there is real rigidity, firms will want to keep p_2^1 close to p_2^2 to avoid getting too far away from other group's price
    - Because the aggregate price does not fully adjust in period 2, output in 2 will be affected by the shock occurring in period 1
• Optimal monetary policy
    - Suppose that $m_t = f_t + v_t$, where f_t is the Fed's monetary policy action and v_t is a random (velocity?) shock to AD

- Assume that v follows a "random walk," so $v_t = v_{t-1} + \varepsilon_t$, with ε being a white noise shock (ε_t is uncorrelated with anything that happened before t)
- The Fed sets f_t based on information known at the beginning of period t, so it has no information advantage over private price-setters
- Suppose that the Fed tries to stabilize output with a policy feedback rule of the form $f_t = \alpha\varepsilon_{t-1}$, where α is the Fed's response to last period's shock.
  - The Fed does not know this period's shock ε_t so this is the best it can do
- Aggregate demand is

$$\begin{aligned} m_t &= f_t + v_t \\ &= \alpha\varepsilon_{t-1} + v_{t-1} + \varepsilon_t \\ &= \alpha\varepsilon_{t-1} + v_{t-2} + \varepsilon_{t-1} + \varepsilon_t \\ m_t &= v_{t-2} + (1+\alpha)\varepsilon_{t-1} + \varepsilon_t \end{aligned}$$

- If everyone knows the Fed's policy rule and parameter α, then
  - $E_{t-1}m_t = v_{t-2} + (1+\alpha)\varepsilon_{t-1}$ because $E_{t-1}\varepsilon_t = 0$, and
    $m_t - E_{t-1}m_t = \left[v_{t-2} + (1+\alpha)\varepsilon_{t-1} + \varepsilon_t\right] - \left[v_{t-2} + (1+\alpha)\varepsilon_{t-1}\right] = \varepsilon_t$
  - $E_{t-2}m_t = v_{t-2}$ because $E_{t-2}\varepsilon_t = E_{t-2}\varepsilon_{t-1} = 0$, and
    $E_{t-1}m_t - E_{t-2}m_t = \left[v_{t-2} + (1+\alpha)\varepsilon_{t-1}\right] - v_{t-2} = (1+\alpha)\varepsilon_{t-1}$
- Then, using the expression for y:

$$\begin{aligned} y_t &= \left[m_t - E_{t-1}m_t\right] + \frac{1}{1+\phi}\left[E_{t-1}m_t - E_{t-2}m_t\right] \\ &= \varepsilon_t + \frac{1+\alpha}{1+\phi}\varepsilon_{t-1} \end{aligned}$$

- What is the optimal choice of α to minimize output fluctuations around optimal value of 0?
  - Fed can't do anything about ε_t
  - Setting $\alpha = -1$ eliminates the effect of lagged shock ε_{t-1}
  - Fed's optimal policy is to offset the one-period lagged shock to "make the previously set price the correct price"

- This was the first of the "new Keynesian" models to provide an explicitly optimal policy rule with a positive stabilizing effect of monetary policy

Fixed-Price Contracts: Taylor Model

- Firms that face price-adjustment costs may not find it easy to set a different price for the two periods.
  - Which is more important, decision-making costs or actual price-adjustment costs?
  - Could be either because both kinds of costs are important
  - Fischer model would reduce decision-making costs because decisions would only need to be made every two periods (costly labor negotiations, for example), but prices would have to adjust every period
- Taylor model assumes that firms set same price $x_t = p_t^1 = p_{t+1}^2$ for both periods of their contract.
  - We also adjust the information assumption to allow them to know m_t before they set x_t

t	1	2	3	4	5	6
Group A	x_1	x_1	x_3	x_3	x_5	x_5
Group B	x_0	x_2	x_2	x_4	x_4	x_6
p_t	$\frac{x_0 + x_1}{2}$	$\frac{x_1 + x_2}{2}$	$\frac{x_2 + x_3}{2}$	$\frac{x_3 + x_4}{2}$	$\frac{x_4 + x_5}{2}$	$\frac{x_5 + x_6}{2}$

- Our probabilities that the currently set price is still in force t periods later are $q_0 = 1,\ q_1 = 1$ and $q_t = 0,\ \forall t > 1$.
  - This means that $\omega_1 = \omega_2 = \frac{1}{2}$ and $\omega_t = 0,\ \forall t > 1$.
  - So optimal $x_t = \frac{1}{2}\left(p_t^* + E_t p_{t+1}^*\right)$
  - Substituting the static-optimal pricing formula:
    $x_t = \frac{1}{2}\left[\left(\phi m_t + (1-\phi) p_t\right) + \left(\phi E_t m_{t+1} + (1-\phi) E_t p_{t+1}\right)\right]$
  - Let's assume that m_t follows a random walk, so $m_t = m_{t-1} + u_t$ and $E_t m_{t+1} = m_t$ because $E_{t-1} u_t = 0$
  - With $p_t = \frac{1}{2}\left(x_{t-1} + x_t\right)$, we have
    $$\begin{aligned} x_t &= \tfrac{1}{2}\left[\phi m_t + \tfrac{1}{2}(1-\phi)\left(x_{t-1} + x_t\right) + \phi m_t + \tfrac{1}{2}(1-\phi)\left(x_t + E_t x_{t+1}\right)\right] \\ &= \phi m_t + \tfrac{1}{4}(1-\phi)\left(x_{t-1} + 2x_t + E_t x_{t+1}\right) \end{aligned}$$
  - Solving for x_t, $x_t = \dfrac{2\phi}{1+\phi} m_t + \frac{1}{2}\dfrac{1-\phi}{1+\phi}\left(x_{t-1} + E_t x_{t+1}\right)$.
- This is a second-order difference equation in x, complicated by the presence of the expectation term
  - Romer does the solution by the method of undetermined coefficients

  - We won't worry about the mathematics of the solution, focus on intuition
- Note from the diagram that x_t must compete against x_{t-1} (which is known) and x_{t+1} (which is not)
  - To the extent that there is real rigidity, firms will want to set x_t in a way that is not too far from these past and future prices.
  - This leads to a long-tailed effect of an AD shock on y
- Suppose that there is a big AD shock u_t in period t
  - Firms setting price in t will not fully adjust because they want/need to compete with firms who set x_{t-1} last period
    - This is just like in the Fischer model where firms' first-period-of-contract price had to compete with the previous contract's price
    - But here, the *same* price x_t holds over into $t + 1$ because they do not get to set different prices for the two periods
  - Firms setting price in $t + 1$ will not *fully* adjust to shock because they have to compete with x_t, which was not fully adjusted
  - Likewise, x_{t+2} will be adjust a little more, but not fully because it must compete against x_{t+1}
  - Full price adjustment to the shock will occur only gradually (asymptotically) over time
  - During adjustment process, $y = m - p$ will be non-zero as the change in p will only gradually match the change in m
- Fischer model: real effects of AD shocks last as long as the longest contract
- Taylor model: real effects of AD shocks die away gradually despite 2-period contracts
  - Formal solution: $y_t = \lambda y_{t-1} + \frac{1}{2}(1+\lambda)u_t$, with $\lambda = \dfrac{1-\sqrt{\phi}}{1+\sqrt{\phi}}$
  - $0 < \phi < 1 \Rightarrow 0 < \lambda < 1$
  - Smaller $\phi \Rightarrow$ more real rigidity and larger λ
  - $\phi = 1 \Rightarrow$ full adjustment to Δm

Calvo Model of Probabilistic Price Adjustment

- This is the model most commonly used in modern sticky-price models
- In each period, a randomly selected fraction α of firms change their prices, with the rest keeping price the same is in the previous period
  - The new price set by firms changing price in t is x_t as in the Taylor model
  - Because share $1-\alpha$ of firms keep same price as last period,
    $p_t = \alpha x_t + (1-\alpha) p_{t-1}$
- For this analysis, Romer re-introduces the discount factor β ($=\dfrac{1}{1+\rho}$) because the lags between price changes can be quite long.
  - We discount future periods at rate β because future profits are less valuable to us
  - Thus, the weight we attach to any future period's static-optimal price is proportional to the "discounted" probability that the price is still in effect $\beta^t q_t$ rather than just to the probability q_t
  - This modifies the definition of ω_t slightly: $\omega_t = \dfrac{\beta^t q_t}{\sum_{\tau=0}^{\infty} \beta^\tau q_\tau}$
  - Substituting in $q_\tau = (1-\alpha)^\tau$, the denominator sum is
    $\sum_{\tau=0}^{\infty} \beta^\tau q_\tau = \sum_{\tau=0}^{\infty} \left[\beta(1-\alpha)\right]^\tau = \dfrac{1}{1-\left[\beta(1-\alpha)\right]}$, so
    $\omega_t = \left[1-\beta(1-\alpha)\right]\beta^t (1-\alpha)^t$
- As usual, the price that the firm sets is
  $x_t = \sum_{\tau=0}^{\infty} \omega_\tau E_t p_{t+\tau}^* = \left[1-\beta(1-\alpha)\right] \sum_{\tau=0}^{\infty} \left[\beta(1-\alpha)\right]^\tau E_t p_{t+\tau}^*$
- From this equation, we can derive the **new Keynesian Phillips (or SRAS) curve** by substitution
  - Following Romer's analysis on pp. 330–331, we separate out the $\tau = 0$ term from the summation to get
    $$x_t = \left[1-\beta(1-\alpha)\right] E_t p_t^* + \left[1-\beta(1-\alpha)\right]\left[\sum_{\tau=1}^{\infty} \beta^\tau (1-\alpha)^\tau E_t p_{t+\tau}^*\right]$$
  - Now note that
    $$\begin{aligned}\left[1-\beta(1-\alpha)\right]\sum_{\tau=1}^{\infty} \beta^\tau (1-\alpha)^\tau E_t p_{t+\tau}^* &= \left[1-\beta(1-\alpha)\right]\beta(1-\alpha)\sum_{\tau=0}^{\infty} \beta^\tau (1-\alpha)^\tau E_t p_{t+\tau+1}^* \\ &= \beta(1-\alpha) E_t x_{t+1}\end{aligned}$$

- $E_t p_t^* = p_t^*$ because it is known at t, so
  $x_t = \left[1-\beta(1-\alpha)\right] p_t^* + \beta(1-\alpha) E_t x_{t+1}$
  - This says that this period's dynamic-optimal price is a weighted average of the current static-optimal price and our current expectation of next period's dynamic-optimal price, with weights $\left[1-\beta(1-\alpha)\right]$ and $\beta(1-\alpha)$
  - The more that we discount the future (either because β is smaller or because α is larger making it less likely that current prices will still be in effect), the greater the weight we put on current static-optimal price and the smaller the weight we put on the future
- The inflation rate is $\pi_t \equiv p_t - p_{t-1} = \alpha x_t + (1-\alpha) p_{t-1} - p_{t-1} = \alpha(x_t - p_{t-1})$
  - Inflation = share of firms changing price × percentage by which those changing price change it
- We can put the x equation into π terms as follows:

  $$x_t - p_t = (x_t - p_{t-1}) - (p_t - p_{t-1}) = \frac{\pi_t}{\alpha} - \pi_t = \left[1-\beta(1-\alpha)\right]\left(p_t^* - p_t\right) + \beta(1-\alpha)\left(E_t x_{t+1} - p_t\right)$$

  From the static-optimal pricing equation, $p_t^* - p_t = \phi y_t$, and
  $E_t \pi_{t+1} = \alpha\left(E_t x_{t+1} - p_t\right)$, so
- $$\frac{\pi_t}{\alpha} - \pi_t = \frac{1-\alpha}{\alpha}\pi_t = \left[1-\beta(1-\alpha)\right]\phi y_t + \frac{\beta(1-\alpha)}{\alpha} E_t \pi_{t+1}$$

  $$\pi_t = \frac{\alpha}{1-\alpha}\left[1-\beta(1-\alpha)\right]\phi y_t + \beta E_t \pi_{t+1} \equiv \kappa y_t + \beta E_t \pi_{t+1}$$

- κ > 0, so this can be thought of as a "Phillips curve" or an SRAS curve relating inflation to expected inflation and output
  - Note that if β = 1, so we ignore discounting, then expected future inflation has a unitary impact on current inflation
  - This looks very much symmetric to the Lucas supply curve and the Friedman-Phelps version of the Phillips curve because $y > 0$ when $\pi > E(\pi)$
  - However, the expectation here is $E_t \pi_{t+1}$, not $E_{t-1} \pi_t$, which leads to some counterfactual implications about inflation dynamics

State-Dependent Pricing

- A major criticism of the models we have studied so far is that the frequency of price changes is exogenous and "time-dependent"
- Alternative is "state-dependent" pricing, where decision to change price depends on how far the price deviates from optimal price, regardless of when price was last set
- Analogy to inventory behavior for retail store:
    - Firms might choose time-dependent ordering policies: order new goods weekly with quantity depending on existing inventories
    - Firms might choose state-dependent ordering policies: order new goods when inventories get below a particular level
- In inventory models and state-dependent price-setting models, the optimal adjustment rule has the form of an **Ss-rule**
    - When $p_i - p_i^*$ falls to some (negative, if $\pi > 0$) threshold level s, it resets price so that $p_i - p_i^*$ is some (positive, if $\pi > 0$) target level S
- Romer's Section 7.5 covers two state-dependent models, but we won't do the details
    - **Caplin-Spulber model**
        - In ongoing inflation, firms' log-prices will zigzag above and below linear trend line (with constant inflation)
        - At any moment in time, firms' log-prices will be evenly distributed along the interval $(p^* + s, p^* + S)$, with $s < 0$.
        - Each time a firm's price drops to $p^* + s < p^*$, it increases price to $p^* + S > p^*$
        - As time passes, each firm's price falls in relation to p^*, but those at the very bottom move to the top to keep average $p = p^*$
        - In Caplin-Spulber model, a change in m is neutral because it simply causes more or fewer firms at the bottom to move to the top, leaving average $m - p$ unchanged
    - **Danziger-Golosov-Lucas model**
        - This is a more realistic, but analytically more complex, model of state-dependent pricing
        - There are both relative and aggregate price shocks (as in Lucas model) and the aggregate shocks may have non-zero expected value so that the trend inflation rate is positive (or negative)
        - Firms respond to their relative price being too far on either side of their target level by raising or lowering price
        - In this model, an unexpected change in AD will affect firms asymmetrically so that more firms on one end will change prices but those on the other end will not have offsetting change

Models with Inflation Inertia

Evidence of inflation inertia

- If the only source of rigidity is price stickiness, then inflation should be trivially easy to stop:
  - Suppose that inflation has been ongoing at 5% forever and that suddenly the growth rate of *m* drops to 0% (assuming *y* has no trend)
  - Now $p_i^* = p_0$, so everyone chooses to keep price constant
    - Inflation stops dead
    - Output does not fall
  - In this model, *price* stickiness leads to *price* inertia, but there is no *inflation* stickiness or *inflation* inertia
- There is substantial evidence that inflation has inertia:
  - Inflation inertia is consistent with backward-looking Phillips curve
    - Backward-looking Phillips curve: $\pi_t = E_{t-1}\pi_t + \kappa\left(y_t - \bar{y}_t\right)$
      - High output is associated with high inflation relative to earlier periods
      - This means that lowering inflation tends to lead to recessions
    - Forward-looking new Keynesian Phillips curve: $\pi_t = E_t\pi_{t+1} + \kappa\left(y_t - \bar{y}_t\right)$
      - High output is associated with high inflation relative to future expectation
      - This means that inflation is expected to fall when output is high
  - Ball's analysis of disinflation finds that reductions in inflation are almost always accompanied by recessions in output
  - Econometric evidence is mixed

Christiano, Eichenbaum, and Evans

- CEE adjust the Calvo model so that it is not changing nominal prices that happens infrequently, but changing real prices
  - Between re-pricing intervals, firms' prices go up at previous period's rate of inflation rather than staying fixed
  - You can think of this as full indexation of the default nominal prices to lagged inflation (similar to wage indexation with $\theta = 1$ in problem set)
  - This kind of adjustment behavior is consistent with costs of deciding on a pricing strategy (decision costs) rather than costs of explicit price changes (menu costs)
- This alters basic pricing equation

  - Calvo: $p_t = (1-\alpha) p_{t-1} + \alpha x_t$
  - CEE: $p_t = (1-\alpha)(p_{t-1} + \pi_{t-1}) + \alpha x_t$
- Romer does the algebra on pp. 345–346 to get

  $\pi_t = \gamma \pi_{t-1} + (1-\gamma) E_t \pi_{t+1} + \chi y_t$, with $\gamma = \dfrac{\beta}{1+\beta} \approx \frac{1}{2}$
  - This equation has both
    - Lagged effects through the indexation by the firms that do not adjust their strategies and
    - Forward-looking effects through anticipatory price-setting by the fraction of firms that do adjust strategies
- The CEE model can explain inflation inertia, but why do firms adjust pricing strategies only periodically and index to lagged inflation in between?

Mankiw-Reis sticky information model

- Mankiw and Reis build a model in which the reason why firms reset pricing strategies infrequently is the cost of acquiring the necessary information
- In the Mankiw-Reis model, each firm can set a price path for current and future dates based on its available information
- They model the arrival of information in a simple way:
  - In each period, a fraction α of firms receives current information about the economy and resets its price path to be optimal given that information
  - The fraction $1 - \alpha$ of firms that do not get new information continue on the price paths that they set in the previous period
- The solution, which we will not study in detail, is
  - $$p_t = \sum_{i=0}^{\infty} a_i \left(E_{t-i} m_t - E_{t-i-1} m_t \right)$$ $$y_t = \sum_{i=0}^{\infty} (1-a_i)\left(E_{t-i} m_t - E_{t-i-1} m_t \right)$$
  - The effect at time t of a new nugget of price information arriving at time $t-i$ is divided between output and price (as it must be if $m = y + p$) with fraction a_i of the effect being on price and $(1 - a_i)$ being on output
  - Romer shows that $a_i = \dfrac{\phi\left[1-(1-\alpha)^{i+1}\right]}{1-(1-\phi)\left[1-(1-\alpha)^{i+1}\right]}$, with ϕ being the elasticity of optimal price with respect to aggregate demand $p_t^* = \phi m_t + (1-\phi) p_t$
- Mankiw and Reis show dynamics of three models in their paper: backward-looking Phillips curve, sticky prices, and sticky information
  - Three shocks:

- One-time fall in m
- Unexpected reduction in growth rate of m
- Anticipated reduction in growth rate of m

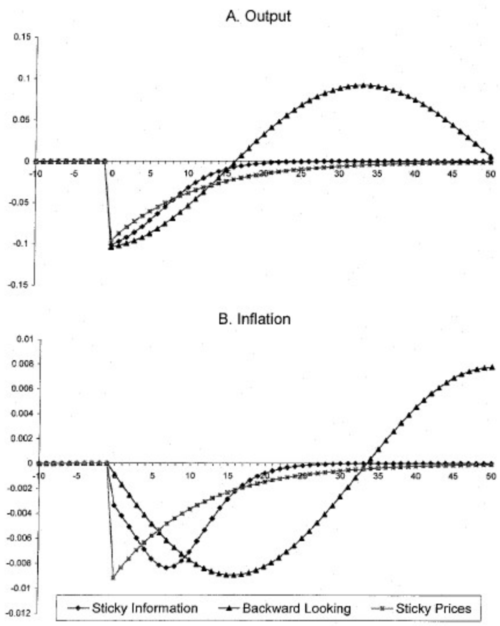

FIGURE I
Dynamic Paths after a 10 Percent Fall in the Level of Aggregate Demand at Time 0

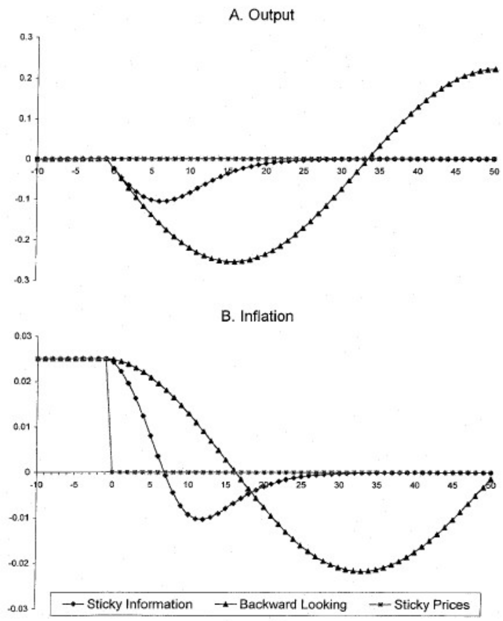

FIGURE II
Dynamic Paths Given an Unanticipated Fall in the Growth Rate of Aggregate Demand at Date 0

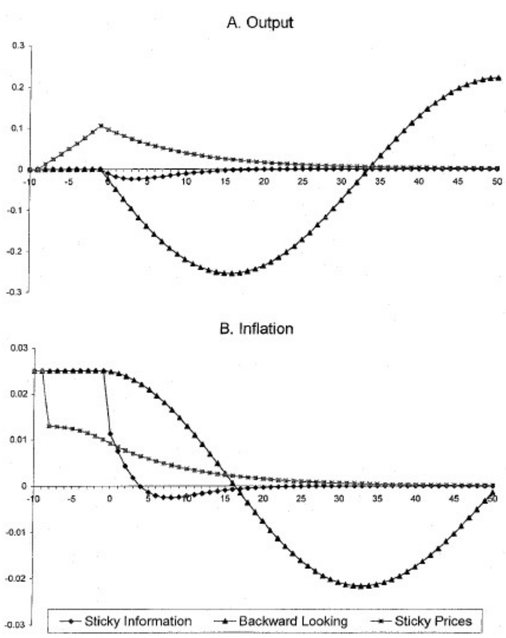

FIGURE III
Dynamic Paths Given an Announcement at Date −8 of a Fall in the Growth Rate of Aggregate Demand at Date 0

New Keynesian DSGE Models

- The world of macroeconomics in the 2000s has been dominated by stochastic simulations of dynamic new Keynesian models
- These models are usually built around
    - New Keynesian IS curve, perhaps with models of investment and consumption grafted on
    - New Keynesian Phillips curve, perhaps with inflation inertia built in through CEE or Mankiw-Reis
    - Monetary-policy function for setting interest rates like the MP curve
- There are many, many variations on this overall framework and a majority of macroeconomic papers in the last ten years uses one
- You could, if you wanted to, explore simulations of these models using Dynare and some of the models that are available publicly